Information page for written examinations at Linköping University

Examination date	2012-05-30
Room (1) If the exam is given in different rooms you have to attach an information paper for each room and mark intended place	U1
Time	14-18
Course code	TDDD48
Exam code	TEN1
Course name **Exam name**	Automatisk planering Skriftlig tentamen
Department	IDA
Number of questions in the examination	5
Teacher responsible/contact person during the exam time	Jonas Kvarnström
Contact number during the exam time	0704-737579
Visit to the examination room approx.	ca kl. 09:00
Name and contact details to the course administrator (name + phone nr + mail)	Anna Grabska Eklund, ankn. 2362, anna.grabska.eklund@liu.se
Equipment permitted	inga
Other important information	
Which type of paper	valfritt

Exam: TDDD48 Automated Planning 2012-05-30

Important Notes

Read the following before you begin!

- While the questions are in English, you may **answer in Swedish** if you prefer!
- *Clear and comprehensible* explanations and motivations are always required. This does not necessarily mean that each answer should be a long essay. What is important is that all the relevant facts are present and clearly explained.
- Concrete examples or counterexamples may be useful as part of a motivation. If so, please make sure you include all relevant information about the example.

1 Fundamental Concepts

Let a *plan* be any action structure that is *executable* – for example, an executable sequence of actions or an executable partially ordered plan.

a) What additional requirements must be satisfied for a plan to be considered a *solution* in (1) satisficing planning, (2) optimizing planning?

Also, why do both of these types of planning exist (what is the advantage of each type over the other)? **(2 points)**

2 Heuristics in State-Space Planning

a) Define (in words or formulas) the optimal delete relaxation heuristic h_+.

Explain in general terms one possible method that allows you to calculate the value $h_+(s)$ for any state s in any planning problem instance.

Is this heuristic always admissible? Explain clearly why. **(3 points)**

b) What is the main difference in the definition of (1) the h_1 heuristic, which belongs to the h_m family of heuristics (where $m \geq 1$), and (2) the h_0 heuristic?

How and why does this difference affect the applicability of these two heuristic functions in optimizing and satisficing planning, respectively? **(2 points)**

c) What is a *landmark*? Explain the general definition and give an example of a concrete landmark from a simple planning domain such as for example Logistics, Blocks World or Towers of Hanoi.

Give an example of how landmarks can be used in the definition of a heuristic function for state-space planning. Keep the description general as opposed to applying it to a specific state or problem instance! **(2 points)**

3 SAT Planning

Recall that SAT planning is based on translations of planning domains and problem instances into propositional satisfiability problems.

a) What is the purpose of *complete exclusion axioms* in SAT planning?

Explain what happens if complete exclusion axioms are omitted, and when (for which type of planning) this may in fact be desirable. **(2 points)**

b) In SAT planning, we need *frame axioms* (for example, *explanatory* frame axioms) to ensure that the SAT solver gives correct results that correspond to valid plans.

Explain how planning could go wrong if frame axioms were not included in the SAT translation of a planning problem.

Demonstrate using a concrete example. The example does not have to involve an entire SAT assignment and SAT formula processed from beginning to end, as this would take considerable time to generate by hand. It is sufficient to illustrate the most central aspects of how the planning process could return invalid plans given a lack of frame axioms. **(2 points)**

4 Planning with Control Rules

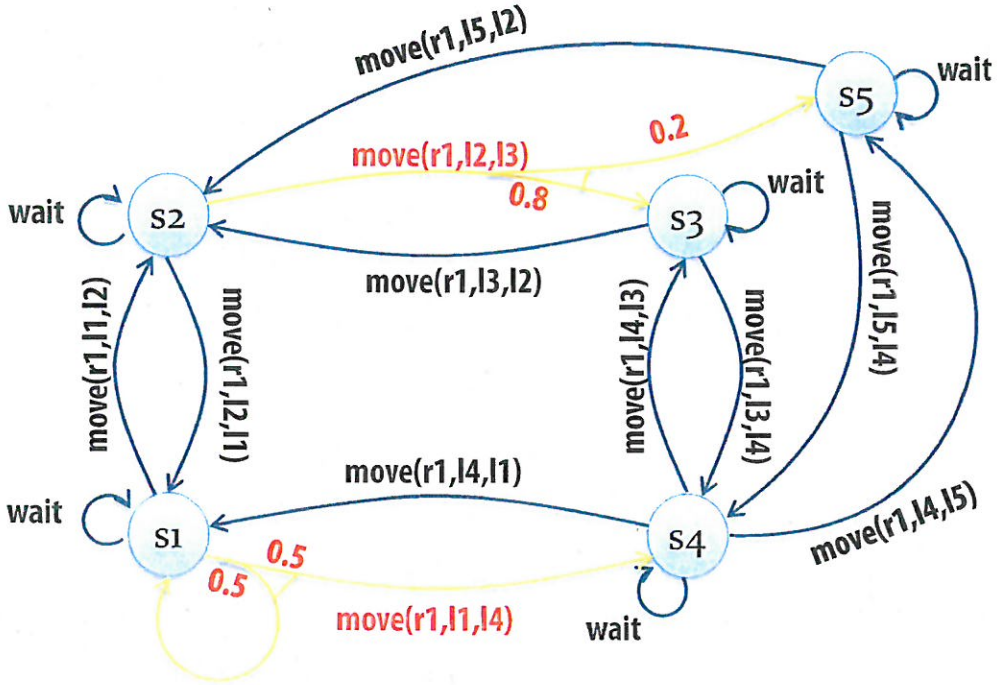
a) What is a *control rule*? Give an example of a reasonable control rule for a domain of your choosing.

The control rule and the domain can either be defined formally or explained clearly in natural language. If you choose to use natural language, make sure all relevant aspects of the rule are still present. In other words, the natural language description should be sufficiently detailed that it maps relatively closely to the formal syntax of the rule language. **(2 points)**

b) How can a control rule be used to guide a planner during forward state space search? For example, you may explain what are the main differences between how a domain-specific control rule provides guidance and how an equally domain-specific *heuristic function* provides guidance, and what happens when a control rule is found to be violated. **(2 points)**

5 Planning with Markov Decision Processes

The following example of a stochastic process has been used during the lectures:



a) Suppose that our objective is to visit states s2 and s4 *repeatedly* (over and over again). For example, we might be generating a policy for a robot that wants to see regularly what happens at each of those two locations.

   Specify costs (for each action) and rewards (for each state) that ensure that this will happen regardless of which state we start in. Assume a discount factor of 0.9. **(1 point)**

b) Begin with an initial policy π_0 such that for any state s, $\pi_0(s) = \text{wait}$. Then perform two full steps of *policy iteration* given your own costs and rewards, creating the policies π_1 and π_2. Show clearly how each step in the policy iteration is calculated, not just the final result. **(2 points)**

We suggest that you abbreviate the move actions so that move(r1,l5,l2) becomes m52, etc.